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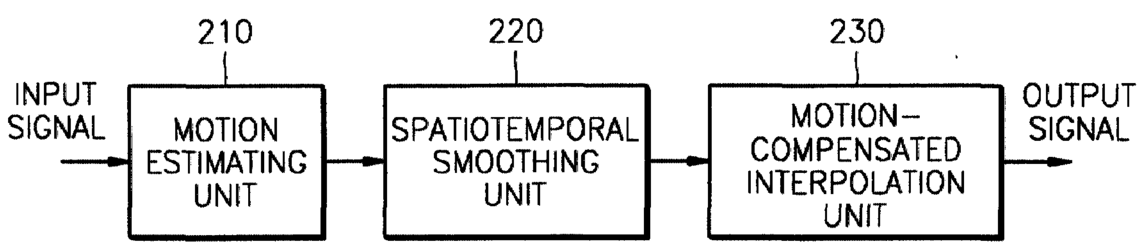
(54) Format converter using bidirectional motion vector and method thereof

(57) A format converter which performs frame rate conversion and de-interlacing using a bidirectional motion vector and a method thereof are provided. The method includes the steps of (a) estimating a bidirectional motion vector between the current frame and the previous frame from a frame to be interpolated; setting the motion vector of a neighboring block that has the minimum error distortion, among motions vectors estimated in the step (a), as the motion vector of the current block; and (c) forming a frame to be interpolated with the motion vector set in the step (b).

FIG. 9



EP 1 164 792 A2

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to an image signal format converter and a method thereof, and more particularly, to a format converter which performs frame rate conversion and de-interlacing using a bidirectional motion vector, and a method thereof.

2. Description of the Related Art

[0002] Generally, in a PC or a high definition TV (HDTV), conversion of a format such as a frame rate and de-interlacing is needed to exchange programs having various signal standards.
[0003] FIG. 1 is a block diagram of a conventional frame rate conversion apparatus.
[0004] Referring to FIG. 1, an image dividing unit 110 divides an image into a changed region and an unchanged region for efficient motion estimation as shown in FIG. 2. The unchanged region is divided again into a covered region, an uncovered region, a background, and an object.
[0005] A motion estimating unit 120 generates the motion vector of a block using a block matching algorithm which is generally used in video coding. In a representative existing block matching algorithm, a motion vector is found out for each block on the assumption that pixels in a predetermined-size block, as shown in FIG. 3, only moved without rotation, magnification, or reduction. In FIG. 3, it is assumed that the motion vector of an N x N size base block located on an arbitrary coordinates (x_c, y_c) in the current frame (f_c) is estimated in a range of $\pm P$ pixels from the previous frame (f_p). Then, the search range in the previous frame is (N+2P) x (N+2P). Therefore, the motion vector is determined as a location which has the maximum correlation among total $(2P+1)^2$ candidate locations. At this time, the difference between the base block in the current frame and the candidate block in the previous frame is calculated as a mean absolute difference (MAD) as the following equation 1:

$$MAD = \frac{1}{N^2}\sum_{i=1}^{N}\sum_{j=1}^{N}\left|f_c(x_c+i, y_c+j) - f_p(x_c+i+m, y_c+j+n)\right| \ldots\ldots(1)$$

[0006] Here, the motion vector of the final block is determined as a location (m, n) of a search range of which the mean absolute difference between the current block and the candidate block is the minimum.
[0007] A spatiotemporal smoothing unit 130 refines an inappropriate motion vector obtained in the motion estimating unit 120, and refines the smoothness of a motion vector as shown in FIG. 4.
[0008] A motion-compensated interpolation unit 140 finds a forward motion vector for the previous frame and the next frame of an image to be interpolated, and using the obtained motion vector, performs bidirectional interpolation according to region classification information generated in the image dividing unit 110. At this time, as shown in FIG. 5, the motion-compensated interpolation using a forward motion vector generates overlaps, where blocks are overlapped because two or more motion vectors are assigned in a frame to be interpolated, and holes where motion vector is not assigned,. These overlaps and holes directly affect the picture quality of an image and degrade the picture quality. Also, since these overlaps and holes have irregular shapes, they should be handled on a pixel-by-pixel basis. Therefore, for the conventional apparatus, complicated signal processing processes and complicated hardware therefor should be implemented to remove the overlaps and holes.
[0009] Also, for an ordinary television video signal, a frequency band is compressed using an interlacing method in which two fields forms a frame. Recently, in a PC or an HDTV which displays generally using a progressive scanning, to display an interlaced image, image lines, which are empty by de-interlacing, are generated by an arbitrary method for progressive scanning.
[0010] FIG. 6 is a conceptual basic diagram of ordinary de-interlacing.
[0011] Referring to FIG. 6, de-interlacing changes a field containing only an odd-numbered pixel, or only an even-numbered pixel, into a frame. At this time, an output frame $F_0(\vec{x}, n)$ is defined as the following equation 2:

$$F_0(\vec{x},n) = \begin{cases} F(\vec{x},n), & (y \bmod 2 = n \bmod 2), \\ F_i(\vec{x},n), & otherwise \end{cases} \quad \ldots\ldots..(2)$$

[0012] Here, $\vec{x}$ means a spatial location, and n is a field number. $F(\vec{x}, n)$ is an input field, and $F_i(\vec{x}, n)$ is a pixel to be interpolated.
[0013] FIG. 7 is a 3 x 3 window for applying edge-based line averaging (ELA) de-interlacing algorithm which does not use motion compensation.
[0014] Referring to FIG. 7, ELA de-interlacing uses correlation between pixels considering direction (x, y) from the location of a pixel to be interpolated as the following equation 3. That is, the mean value of pixels neighboring a pixel to be interpolated and pixels to be interpolated in the previous field and the next field of the field to be interpolated is output:

$$F_0(\vec{x},n) = \begin{cases} F(\vec{x}-\vec{u}_x-\vec{u}_y,n)+F(\vec{x}+\vec{u}_x+\vec{u}_y,n)/2, & if\ \min(a,b,c)=a, \\ F(\vec{x}-\vec{u}_x+\vec{u}_y,n)+F(\vec{x}+\vec{u}_x-\vec{u}_y,n)/2, & if\ \min(a,b,c)=b, \\ F(\vec{x}-\vec{u}_y,n)+F(\vec{x}+\vec{u}_y,n)/2, & otherwise \end{cases}$$

$$here,\ a=\left|F(\vec{x}-\vec{u}_x-\vec{u}_y,n)-F(\vec{x}+\vec{u}_x+\vec{u}_y,n)\right|$$

$$b=\left|F(\vec{x}-\vec{u}_x+\vec{u}_y,n)-F(\vec{x}+\vec{u}_x-\vec{u}_y,n)\right|$$

$$c=\left|F(\vec{x}-\vec{u}_y,n)-F(\vec{x}+\vec{u}_y,n)\right| \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(3)$$

[0015] FIG. 8 is a conceptual diagram for explaining an ordinary time-recursive (TR) de-interlacing method.
[0016] Referring to FIG. 8, TR de-interlacing using a motion vector assumes that the previous field (n-1) is perfectly de-interlaced, and the missing data of the current field (n) is compensated with a motion vector. A pixel to be interpolated can be the original pixel of the previous field, or a previously interpolated pixel. Therefore, a pixel to be interpolated can be expressed as the following equation 4:

$$F_0(\vec{x},n) = \begin{cases} F(\vec{x},n), & (y \bmod 2 = n \bmod 2), \\ F(\vec{x}-\vec{d}(\vec{x},n),n-1), & otherwise \end{cases} \quad \ldots\ldots..(4)$$

[0017] However, since ELA de-interlacing method does not use motion compensation, flickering occurs in a region where motions exist, and since TR de-interlacing method is continuously de-interlaced, an error occurred in an arbitrary field can be propagated to other fields.

SUMMARY OF THE INVENTION

[0018] To solve the above problems, it is an object of the present invention to provide a frame rate converting method which refines a picture quality by directly obtaining a bidirectional motion vector of two continuous frames for a pixel to be interpolated.
[0019] It is another object to provide a frame rate converter using the frame rate converting method.
[0020] It is another object to provide a de-interlacing method which by estimating a bidirectional motion vector between two continuous fields for a pixel to be interpolated, is easy to perform and has an excellent outline-keeping ability.
[0021] It is another object to provide a de-interlacing apparatus using the de-interlacing method.

[0022] It is another object to provide a de-interlacing apparatus which can enhance reliability of motion information and reduce errors in a pixel to be interpolated by adaptively selecting between motion-compensated interpolation value and spatiotemporal interpolation value according to the degree of motion of an input image.

[0023] To accomplish the above object of the present invention, there is provided a frame rate converting method having the steps of (a) estimating a bidirectional motion vector for a frame to be interpolated using motion vectors between the current frame and the previous frame; (b) setting the motion vector of a neighboring block that has the minimum error distortion, among motions vectors estimated in the step (a) in a frame to be interpolated, as the motion vector of the current block; and (c) forming a frame to be interpolated with the motion vector set in the step (b).

[0024] To accomplish another object of the present invention, there is also provided a frame rate converter having a bidirectional motion estimating means for obtaining the motion vector between the current frame and the previous frame, assigning the motion vector to a frame to be interpolated, and estimating the assigned motion vector for a frame to be interpolated; a spatiotemporal smoothing unit for evaluating the accuracy of the motion vector of the current block in the frame to be interpolated in the bidirectional motion estimating means, and then setting the motion vector of a neighboring block, which has the minimum error distortion, as the motion vector of the current block; and an interpolation unit for extending the block to be interpolated, and interpolating with the motion vector obtained in the spatiotemporal smoothing unit in an overlapped region with different weights.

[0025] To accomplish another object of the present invention, there is also provided a de-interlacing method having (a) estimating a bidirectional motion vector for a pixel to be interpolated using motion vectors between the previous field and the next field; (b) setting the motion vector of which neighboring error distortion is the minimum in the step (a) as the motion vector of a pixel to be interpolated; and (c) forming the pixel to be interpolated with the motion vector set in the step (b).

[0026] To accomplish another object of the present invention, there is also provided a de-interlacing apparatus having a bidirectional motion estimating means for obtaining the motion vector between the current field and the previous field, assigning the motion vector to a field to be interpolated, and estimating the assigned motion vector for a field to be interpolated; a spatiotemporal smoothing unit for evaluating the accuracy of the motion vector of the current block in the field to be interpolated in the bidirectional motion estimating means, and then setting the motion vector of a neighboring block, which has the minimum error distortion, as the motion vector of the current block; and a signal converting unit for forming a pixel of a line having no data, with the median value of pixel values obtained by applying the motion vector set in the spatiotemporal smoothing unit, the mean value of the pixel values, and the values of pixels vertically neighboring the pixel to be interpolated.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] The above objects and advantages of the present invention will become more apparent by describing in detail a preferred embodiment thereof with reference to the attached drawings in which:

FIG. 1 is a block diagram of a conventional frame rate conversion apparatus;
FIG. 2 is a diagram for explaining an image dividing method in the image dividing unit of FIG. 1;
FIG. 3 is a diagram for explaining a motion estimating method in the motion estimating unit of FIG. 1;
FIG. 4 illustrates a screen before refinement and a screen after refinement in the spatiotemporal smoothing unit of FIG. 1;
FIG. 5 is an example of the structure of an image interpolated by motion compensation in the motion-compensated interpolation unit of FIG. 1;
FIG. 6 is a conceptual basic diagram of ordinary de-interlacing;
FIG. 7 is a 3x3 window for applying edge-based line averaging (ELA) de-interlacing algorithm which does not use motion compensation;
FIG. 8 is a diagram for explaining motion vector estimation for each block in the spatiotemporal smoothing unit of FIG. 6;
FIG. 9 is a block diagram of a frame rate conversion apparatus according to the present invention;
FIGS. 10A through 10C are conceptual diagrams for obtaining a bidirectional motion vector;
FIG. 11 is a conceptual diagram for refining a motion vector of the spatiotemporal smoothing unit of FIG. 9;
FIG. 12 is a conceptual diagram for explaining a motion-compensated interpolation method of the refined motion-compensated interpolation unit of FIG. 9;
FIG. 13 is a block diagram of a de-interlacing apparatus according to the present invention;
FIG. 14 is a conceptual diagram for showing decimation conversion of the motion estimating unit of FIG. 13;
FIG. 15 is a conceptual diagram for showing motion-compensated de-interlacing in the signal conversion unit of FIG. 13;
FIG. 16 is a conceptual diagram for showing spatiotemporal interpolation using a median filter in the signal con-

version unit of FIG. 13; and

FIG. 17 is another embodiment of a de-interlacing apparatus according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0028] Hereinafter, embodiments of the present invention will be described in detail with reference to the attached drawings. The present invention is not restricted to the following embodiments, and many variations are possible within the spirit and scope of the present invention. The embodiments of the present invention are provided in order to more completely explain the present invention to anyone skilled in the art.

[0029] FIG. 9 is a block diagram of a frame rate conversion apparatus according to the present invention

[0030] The apparatus of FIG. 9 includes a motion estimating unit 210, a spatiotemporal smoothing unit 220, and a refined motion-compensated interpolation unit 230.

[0031] Referring to FIG. 9, the motion estimating unit 210 obtains a motion vector between the current frame and the previous frame, and assigns the motion vector to a frame to be interpolated, and estimates a bidirectional motion vector for the frame to be interpolated.

[0032] The spatiotemporal smoothing unit 220 evaluates the accuracy of the motion vector of the current block estimated in frame to be interpolated, and then sets a motion vector of neighboring blocks, of which error distortion is the minimum, to the motion vector of the current block.

[0033] The refined motion-compensated interpolation unit 230 forms a block to be interpolated with the mean of blocks in the previous frame and the next frame of the frame to be interpolated, using the motion vector obtained in the spatiotemporal smoothing unit 220. At this time, the refined motion-compensation interpolation unit 230 extends the block to be interpolated and interpolates with different weights in an overlap region.

[0034] FIGS. 10A through 10C are conceptual diagrams for obtaining a bidirectional motion vector.

[0035] First, in two neighboring frames, F_{n-1} is (n-1)-th frame, F_{n+1} is (n+1)-th frame, and F_n is n-th frame. In the n-th frame (F_n), as shown in FIGS. 10A through 10C, a bidirectional motion vector is obtained through a motion vector initialization state (FIGS. 10A and 10B) and a motion vector adjusting stage (FIG. 10C).

[0036] Referring to FIG. 10A, the motion vector initialization stage will now be explained.

[0037] First, (n-1)-th frame/field (F_{n-1}) and (n+1)-th frame/field (F_{n+1}) are decimated in 2:1 ratio, and reconstructed to (n-1)-th frame/field (F_{n-1}) and (n+1)-th frame/field (F_{n+1}).

[0038] Then, as shown in FIG. 10A, the (n+1)-th frame/field ($\hat{F}_{n+1}$) is divided into a plurality of blocks, and a search range for each block is determined. Then, in the search range, by applying a block matching algorithm (BMA), a forward motion vector (MV) is estimated. Then, as shown in FIG. 10B, the n-th frame/field ($\hat{F}_n$) to be interpolated is divided by block, and the estimated forward MV is set as an initial MV of the n-th frame/field (F_n) to be interpolated. Therefore, by compensating a motion according to the block grid of each block using a bidirectional motion vector as shown in FIG. 10B, overlaps and holes do not occur in the existing video signal.

[0039] Next, referring to FIG. 10C, the motion vector adjusting stage will now be explained. First, since the forward MV is used in the initialization stage, the initial MV obtained in the motion vector initialization stage changes a little. To correct this, taking the forward MV obtained in the motion vector initialization stage as an initial value, a small search range (± d) is newly set. Then, using BMA again in the small search range (± d), the motion vector set in the initial stage is corrected, and then a bidirectional motion vector is generated. To explain the adjusting stage for the initial MV shown in FIG. 10C, an arbitrary block (B_{ti}) in the n-th frame/field (F_n) to be interpolated is considered. The center of the block (B_{ti}) is (x,y), and corresponds to the initial MV (($\vec{D}_i$) = (h, v)) . At this time, the initial MV ($\vec{D}_i$) simultaneously shows the motion between the n-th frame/field (F_n) to be interpolated for the arbitrary block (B_{ti}) and (n+1)-th frame/field (F_{n+1}) and the motion from the (n-1)-th frame/field (F_{n-1}) to the n-th frame/field (F_n) to be interpolated. Then, if the arbitrary block (B_{ti}) on the n-th frame/field (F_n) to be interpolated moves by the initial MV ($\vec{D}_i$), the arbitrary block (B_{ti}) is generated by the block (B_{t1}) of the (n-1)-th frame/field (F_{n-1}) and the block (B_{t2}) of the (n+1)-th frame/field (F_{n+1}). That is, the centers of the initial block (B_{t1})and block (B_{t2}) can be expressed as the following equation 5:

$$B_{t1}(x_{t1},y_{t1}) = (x, y)-(h, v) = (x-h, y+v)$$

$$B_{t2}\ (x_{t2},y_{t2})= (x, y)+(h, v) = (x+h, y+v) \qquad (5)$$

[0040] Here, the arbitrary block (B_{ti}) is located on a fixed location, and each of block (B_{t1}) and block (B_{t2}) moves from the initial location within the search range (± d). At this time, if the n-th frame/field (F_n) should be located in the center between the (n-1)-th frame/field (F_{n-1}) and the (n+1)-th frame/field ($\hat{F}_{n+1}$), the motion between the block (B_{t1}) and the arbitrary block (B_{ti}) should be the same as the motion between the arbitrary block (B_{ti}) and the block (B_{t2}). For this, on

the motion trajectory of the initial MV, the block (B_{t1}) and the block (B_{t2}) should move symmetrically from the center of the block (B_{ti}) to be interpolated.

[0041] Therefore, the number of possible combinations in case of having search range ($\pm d$) is $(2d + 1)^2$. After this process, the bidirectional vector between the (n-1)-th frame/field (F_{n-1}) and the (n+1)-th frame/field (F_{n+1}) for the n-th frame/field (F_n) is obtained. At this time, if the n-th frame/field (F_n) should be at the center between the (n-1)-th frame/field (F_{n-1}) and the (n+1)-th frame/field (F_{n+1}), the motion vector to each direction has the same value.

[0042] FIG. 11 is a conceptual diagram for refining a motion vector of the spatiotemporal smoothing unit 220 of FIG. 9.

[0043] Referring to FIG. 11, first, in the frame/field to be interpolated, the current block is set as MV_0, candidate MV blocks surrounding the current block are set as MV_i (i=1,..,8), and the motion vector of the block is set as $D(\cdot)$. Then, the motion vector of a block having the minimum MAD among the motion vectors of the candidate blocks is set as the motion vector of the current block. That is, as the following equation 6, using the bidirectional motion vector between two neighboring frame/fields, the displaced frame difference (DFD) of the current block is obtained and then the motion vector of the candidate block having the minimum DFD is set as the motion vector of the current block. In conclusion, the spatiotemporal smoothing refines picture quality by removing inappropriate motion vector detected in the motion estimation.

$$DFD(D) = \sum_{p \in B(p)} \left| f_{t1}(p - D) - f_{t2}(p + D) \right| \ldots\ldots.(6)$$

[0044] FIG. 12 is a conceptual diagram for explaining a motion-compensated interpolation method of the refined motion-compensated interpolation unit 230 of FIG. 9

[0045] Referring to FIG. 12, the refined motion-compensated interpolation unit 230 forms a frame to be interpolated after taking the block mean of the two neighboring frames as the following equation 7 using the motion vector obtained bidirectionally. At this time, the frame to be interpolated extends the original block size horizontally and vertically, and is interpolated in the overlapped region with different weights.

$$f_{ti}(p) = \frac{1}{2}[f_{t1}(p - D(B(p))) - f_{t2}(p - D(B(p)))] \qquad (7)$$

[0046] FIG. 13 is a block diagram of a de-interlacing apparatus according to the present invention.

[0047] Referring to FIG. 13, F_{n-1}, which is input first, is (n-1)-th field, F_n is n-th field, and F_{n+1} is (n+1)-th field. $\tilde{F}_n$ is a video signal which is converted from the n-th field (F_n) for progressive scanning.

[0048] A motion estimating unit 410 obtains the motion vector of the n-th field (F_n), which corresponds to the location of the field to be interpolated, after obtaining the bidirectional motion vector, from the (n-1)-th field (F_{n-1}) and the (n+1)-th field (F_{n+1}). The bidirectional motion vector to be obtained in the n-th field (F_n) is obtained by calculating the fields, for which decimation conversion have been performed, through the motion vector initialization stage (FIGS. 10A and 10B) and the motion vector adjusting stage (FIG. 10C). As a result, for the field to be interpolated, the bidirectional motion vector between the previous field and the next field is calculated.

[0049] A spatiotemporal smoothing unit 420, as described in FIG. 11, obtains a bidirectional motion vector, which is smoothed through spatiotemporal smoothing, because bidirectional motion vectors obtained in the motion estimating unit 410 have some discontinuity.

[0050] A signal converting unit 430 is an interlaced-to-progressive conversion block, restores no-data lines of n-th field (F_n) with the mean of pixels to which bidirectional motion vectors generated in the spatiotemporal smoothing unit 420 are applied, and outputs the final frame ($\tilde{F}_n$).

[0051] FIG. 14 is a conceptual diagram for showing decimation conversion of the motion estimating unit 410 of FIG. 13.

[0052] Referring to FIG. 14, the (n-1)-th field (F_{n-1}) and the (n+1)-th field (F_{n+1}) are input and reconstructed to the (n-1)-th field (F_{n-1}) and the (n+1)-th field (F_{n+1}), only with the lines having data. That is, the reconstructed (n-1)-th field (F_{n-1}) and (n+1)-th field (F_{n+1}) are reduced from the input (n-1)-th field (F_{n-1}) and (n+1)-th field (F_{n+1}) by half vertically. Therefore, the reconstructed (n-1)-th field (F_{n-1}) and (n+1)-th field (F_{n+1}) are decimated in a 2:1 ratio vertically and horizontally.

[0053] FIG. 15 is a conceptual diagram for showing motion-compensated de-interlacing in the signal conversion unit 430 of FIG. 13.

[0054] Referring to FIG. 15, no-data lines of the n-th field (F_n) is restored, using the bidirectional motion vector of the field (F_n) to be interpolated. The restoration process can be expressed as the following equation 8:

$$\widetilde{F}_n = \frac{F_{n-1}(x-h, y-v) + F_{n+1}(x+h, y+v)}{2} \quad ....(8)$$

[0055] Here, x and y are the abscissa value and the ordinate value respectively in each field, and h and v are the horizontal component and the vertical component, respectively, of the bidirectional motion vector.
[0056] FIG. 16 is a conceptual diagram for showing spatiotemporal interpolation using a median filter in the signal conversion unit of FIG. 13.
[0057] The performance of a de-interlacing method is affected greatly by the result of motion estimation. Therefore, to reduce an error in motion estimation, no data lines in the field (F_n) to be interpolated are interpolated using a median filter as shown in FIG. 16, and it can be expressed as the following equation 9:

$$\widetilde{F}_n(\vec{p}) = \begin{cases} F_n(\vec{p}), & \text{if } \vec{p} \text{ is in the existing line}, \\ Median(A, B, C, D, \frac{(C+D)}{2}), & \text{otherwise}, \end{cases} \quad ....(9)$$

[0058] Here, pixels A, B, C, and D are defined as follows:

$$A = F_n(\vec{p} - \vec{u}_y),\ B = F_n(\vec{p} + \vec{u}_y),\ C = F_{n-1}(\vec{p} - \vec{D}),\ D = F_{n+1}(\vec{p} + \vec{D})$$

[0059] Here, $\vec{D}$ is a bidirectional motion vector, $\vec{u}_y$ is $(0, 1)^T$, and (C+D)/2 is the resulting value of the motion-compensated de-interlacing as the equation 9.
[0060] As this, if the median filter is used, the frame ($\hat{F}_n$) to be finally output takes the original pixel if the line has data, and otherwise is interpolated with the median value of the pixel (C) of the (n-1)-th field, the pixel (D) of the (n+1)-th field, pixels (A, B) which are vertically neighboring the pixel (Z) to be interpolated in the n-th field, and de-interlaced pixel ((C+D)/2), as the pixel (Z) of the n-th field.
[0061] FIG. 17 is another embodiment of a de-interlacing apparatus according to the present invention.
[0062] Referring to FIG. 17, a motion-compensated interpolation unit 172 interpolates with the mean of pixels using the interpolation value of a frame, that is a motion vector, as shown in FIG. 13 according to the present invention, or outputs the median value of pixel values, to which a motion vector is applied, the mean value of the pixels, and the value between two pixels which are vertically neighboring a pixel to be interpolated.
[0063] A spatiotemporal interpolation unit 176 outputs the mean value of pixels neighboring a pixel to be interpolated and pixels on the locations to be interpolated in the previous field and the next field of the field to be interpolated, as the interpolation value of a frame.
[0064] A motion evaluation unit 174 evaluates the degree of motion using the MAD value of the current block calculated in the motion estimating unit 410 of FIG. 13.
[0065] A motion adaptation unit 178 sets the value of a pixel to be finally interpolated by adaptively calculating the output value of the motion-compensated interpolation unit 172 and the output value of the spatiotemporal interpolation unit 176 according to the degree of motion evaluated in the motion evaluation unit 174.
[0066] Therefore, the de-interlacing apparatus of FIG. 17 prevents the error which occurs when an inaccurate motion vector is used in the process for determining the presence of a motion.
[0067] As described above, according to the present invention, by obtaining the bidirectional motion vector between two frames for a frame to be interpolated, overlaps and holes do not occur. Therefore, picture quality can be improved and particularly, panning or zooming image having a camera motion can be efficiently processed. Also, noise on a time axis between fields and flickers between lines, which occur in the existing method, can be reduced, and the ability to keep outlines is better than the existing de-interlacing methods. Also, by adaptively selecting between a motion-compensated interpolation value and a spatiotemporal interpolation value according to the degree of the motion of an input image, reliability of information on a motion is enhanced compared to the method simply using a motion-compensated interpolation value, and artifact can be efficiently reduced.

Claims

1. A frame rate converting method comprising the steps of:

   (a) estimating a bidirectional motion vector for a frame to be interpolated using motion vectors between the current frame and the previous frame;
   (b) setting the motion vector of a neighboring block that has the minimum error distortion, among motions vectors estimated in the step (a) in a frame to be interpolated, as the motion vector of the current block; and
   (c) forming a frame to be interpolated with the motion vector set in the step (b).

2. The method of claim 1, wherein the step (a) further comprises the sub-steps of:

   (a-1) detecting a motion vector between the current frame and the previous frame, and assigning the motion vector to a frame to be interpolated; and
   (a-2) adjusting the motion vector assigned in the step (a-1) in the frame to be interpolated according to a block grid.

3. The method of claim 2, wherein the detecting in the step (a-1) further comprises the steps of:

   decimating an image; and
   estimating a motion vector from the decimated image.

4. The method of claim 2, wherein the step (a-2) is the step for estimating a value, which has the minimum error among blocks of the previous frame and the current frame which linearly pass through the center of a block formed according to the block grid, as the bidirectional motion vector of the frame block to be interpolated in the frame to be interpolated.

5. The method of claim 1, wherein the step (b) includes the step for evaluating the accuracy of the motion vector of the current block in the frame to be interpolated and setting the motion vector of neighboring block which has the minimum error distortion, as the motion vector of the current block.

6. The method of claim 1, wherein the step (b) includes the steps of:

   assigning a motion vector for the frame to be interpolated;
   evaluating the accuracy of the motion vector of the current block; and
   setting the motion vector of a neighboring block which has the minimum error distortion, as the motion vector of the current block.

7. The method of claim 1, wherein in the step (c) a block to be interpolated is formed with the mean of blocks, using the estimated motion vector in a frame to be interpolated.

8. The method of claim 1, wherein in the step (c) the block to be interpolated is extended and interpolated in an overlapped region with different weights.

9. A frame rate converter comprising:

   a bidirectional motion estimating means for obtaining the motion vector between the current frame and the previous frame, assigning the motion vector to a frame to be interpolated, and estimating the assigned motion vector for a frame to be interpolated;
   a spatiotemporal smoothing unit for evaluating the accuracy of the motion vector of the current block in the frame to be interpolated in the bidirectional motion estimating means, and then setting the motion vector of a neighboring block, which has the minimum error distortion, as the motion vector of the current block; and
   an interpolation unit for extending the block to be interpolated, and interpolating with the motion vector obtained in the spatiotemporal smoothing unit in an overlapped region with different weights.

10. A de-interlacing method comprising:

   (a) estimating a bidirectional motion vector for a pixel to be interpolated using motion vectors between the

previous field and the next field;
(b) setting the motion vector of which neighboring error distortion is the minimum in the step (a) as the motion vector of a pixel to be interpolated; and
(c) forming the pixel to be interpolated with the motion vector set in the step (b).

11. The de-interlacing method of claim 10, wherein the step (a) further comprises the sub-steps of:

(a-1) detecting the motion vector between the current field and the previous field, and assigning the motion vector to a field to be interpolated; and
(a-2) adjusting the motion vector assigned in the step (a-1) according to a block grid in a frame to be interpolated.

12. The de-interlacing method of claim 10, wherein the step (a-2) is the step for estimating a location value, which has the minimum error among blocks of the previous field and the current field which linearly pass through the center of block formed according to the block grid in the field to be interpolated, as the bidirectional motion vector of the block of the field to be interpolated.

13. The de-interlacing method of claim 10, wherein the step (b) includes the step for evaluating the accuracy of the motion vector of the current block in the field to be interpolated and setting the motion vector of neighboring block which has the minimum error distortion, as the motion vector of the current block.

14. The de-interlacing method of claim 10, wherein the step (b) includes the steps of:

adjusting a motion vector for the field to be interpolated;
evaluating the accuracy of the motion vector of the current block; and
setting the motion vector of a neighboring block which has the minimum error distortion, as the motion vector of the current block.

15. The de-interlacing method of claim 10, wherein in the step (c) a pixel to be interpolated is formed with the mean of pixels, using the estimated motion vector in a field to be interpolated.

16. The de-interlacing method of claim 10, wherein in the step (c) the median value of pixel values, to which the estimated motion vector is applied, of the previous field and the next field of the field to be interpolated, the mean value of the pixels, and the values of two pixels vertically neighboring a pixel to be interpolated, is set to a pixel to be interpolated.

17. The de-interlacing method of claim 10, wherein in the step (c) the field to be interpolated takes the original pixel if the line has data, and otherwise, takes the median value of the pixel value on the same location of the (n-1)-th field, the pixel value on the same location of the (n+1)-th field, the values of pixels vertically neighboring the pixel to be interpolated in the n-th field, and the mean value of these pixel values.

18. A de-interlacing apparatus comprising:

a bidirectional motion estimating means for obtaining the motion vector between the current field and the previous field, assigning the motion vector to a field to be interpolated, and estimating the assigned motion vector for a field to be interpolated;
a spatiotemporal smoothing unit for evaluating the accuracy of the motion vector of the current block in the field to be interpolated in the bidirectional motion estimating means, and then setting the motion vector of a neighboring block, which has the minimum error distortion, as the motion vector of the current block; and
a signal converting unit for forming a pixel of a line having no data, with the median value of pixel values obtained by applying the motion vector set in the spatiotemporal smoothing unit, the mean value of the pixel values, and the values of pixels vertically neighboring the pixel to be interpolated.

19. An adaptive de-interlacing apparatus comprising:

a motion evaluating unit for evaluating the degree of motion referring to the value of a motion vector of which error distortion between blocks of the previous field and the current field is the minimum;
a motion-compensated interpolation unit for interpolating with the mean of pixels to which bidirectional motion

vector detected for a pixel to be interpolated is applied, or interpolating with the median value of pixel values, to which a motion vector is applied, the mean value of the pixels, and the value between two pixels vertically neighboring the pixel to be interpolated;
a spatiotemporal interpolation unit for interpolating with the mean value of pixels neighboring the pixel to be interpolated and pixels to be interpolated in the previous field and the next field of the field to be interpolated; and
a motion adaptation unit for adaptively selecting between the interpolation value of the motion-compensated interpolation unit and the interpolation value of the spatiotemporal interpolation unit according to the degree of motion evaluated in the motion evaluating unit.

20. An adaptive frame rate converter comprising:

a motion evaluating unit for evaluating the degree of motion referring to the value of a motion vector of which error distortion between blocks of the previous frame and the current frame is the minimum;
a motion-compensated interpolation unit for interpolating with the mean of pixels to which bidirectional motion vector detected for a frame to be interpolated is applied;
a spatiotemporal interpolation unit for interpolating with the mean value of pixels neighboring the pixel to be interpolated and pixels to be interpolated in the previous frame and the next frame of the frame to be interpolated; and
a motion adaptation unit for adaptively selecting between the interpolation value of the motion-compensated interpolation unit and the interpolation value of the spatiotemporal interpolation unit according to the degree of motion evaluated in the motion evaluating unit.

FIG. 1

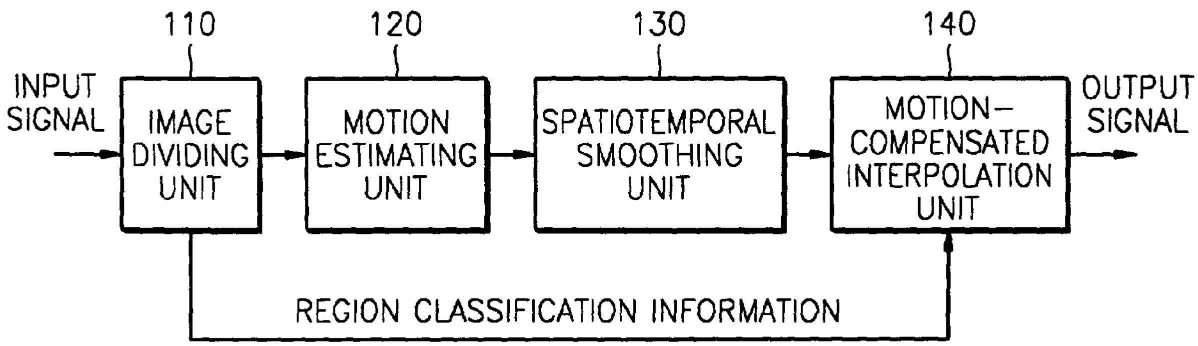

110
120
130
140
INPUT SIGNAL
IMAGE DIVIDING UNIT
MOTION ESTIMATING UNIT
SPATIOTEMPORAL SMOOTHING UNIT
MOTION-COMPENSATED INTERPOLATION UNIT
OUTPUT SIGNAL
REGION CLASSIFICATION INFORMATION

FIG. 2

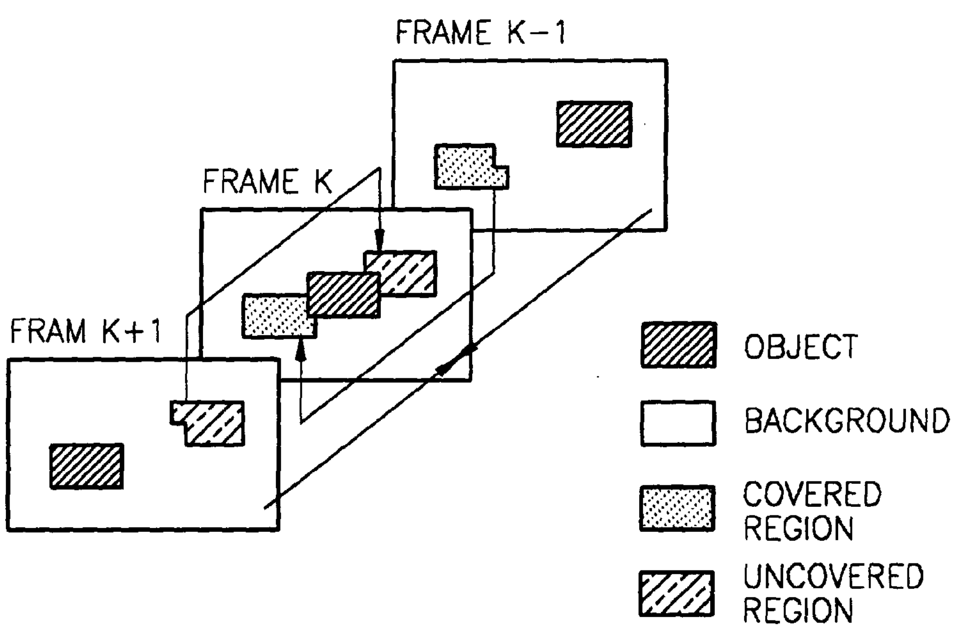

FRAME K-1
FRAME K
FRAM K+1
OBJECT
BACKGROUND
COVERED REGION
UNCOVERED REGION

FIG. 3

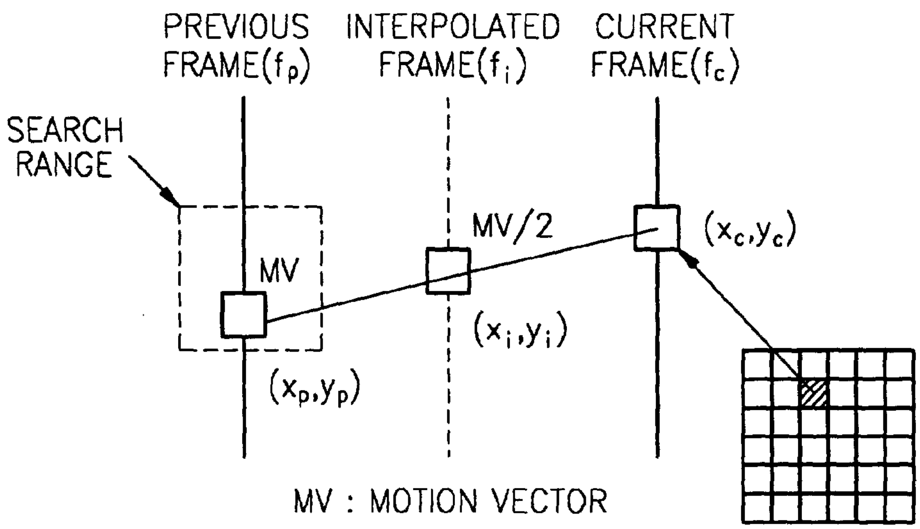
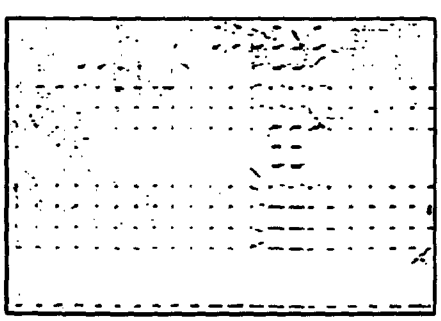
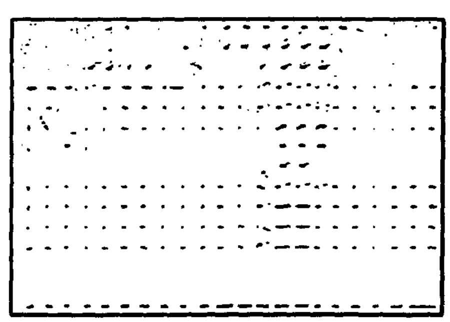


FIG. 4



MOTION FIELD BEFORE REFINEMENT



MOTION FIELD AFTER REFINEMENT

FIG. 5

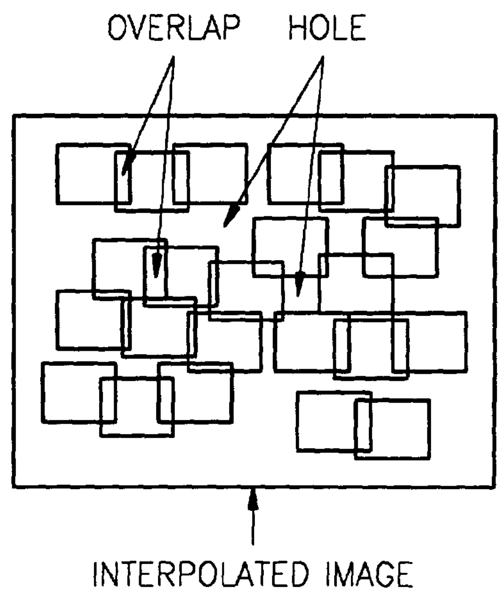

OVERLAP
HOLE
INTERPOLATED IMAGE

FIG. 6

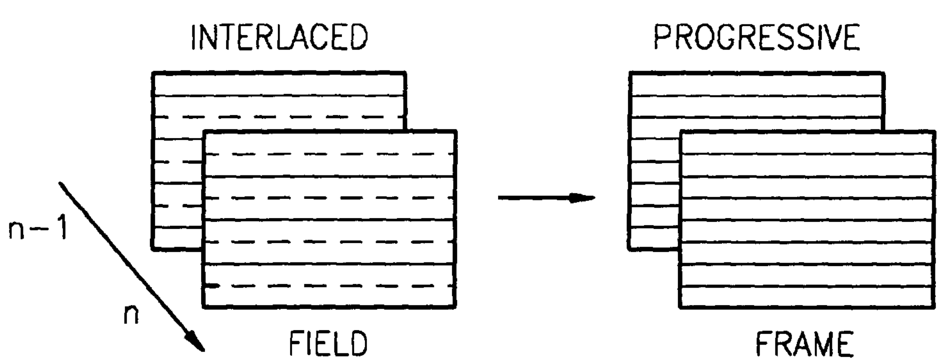

INTERLACED
PROGRESSIVE
n-1
n
FIELD
FRAME

FIG. 7

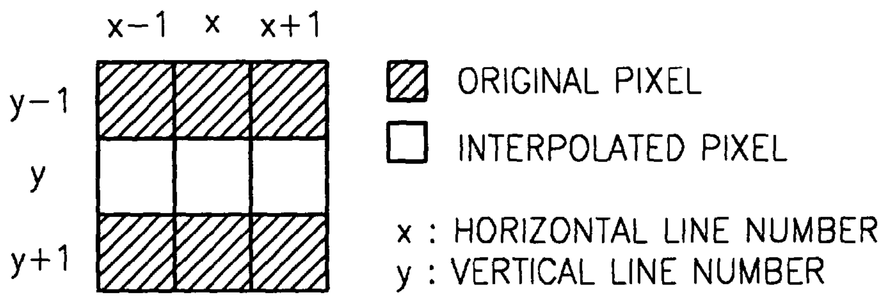

x−1
x
x+1
y−1
y
y+1
ORIGINAL PIXEL
INTERPOLATED PIXEL
x : HORIZONTAL LINE NUMBER
y : VERTICAL LINE NUMBER

FIG. 8

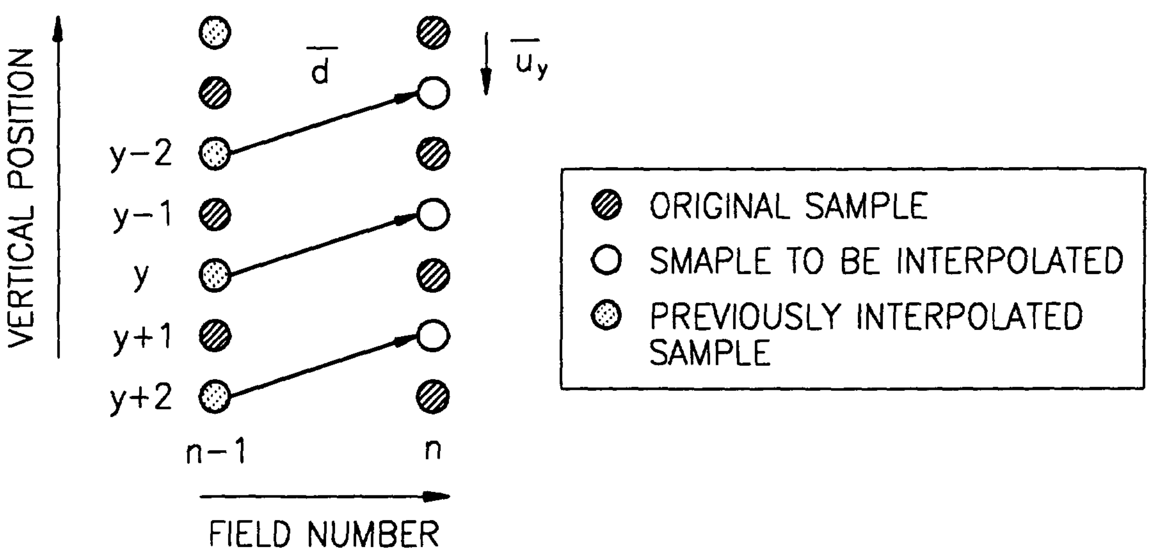

VERTICAL POSITION
d
u y
y−2
y−1
y
y+1
y+2
n−1
n
FIELD NUMBER
ORIGINAL SAMPLE
SMAPLE TO BE INTERPOLATED
PREVIOUSLY INTERPOLATED SAMPLE

FIG. 9

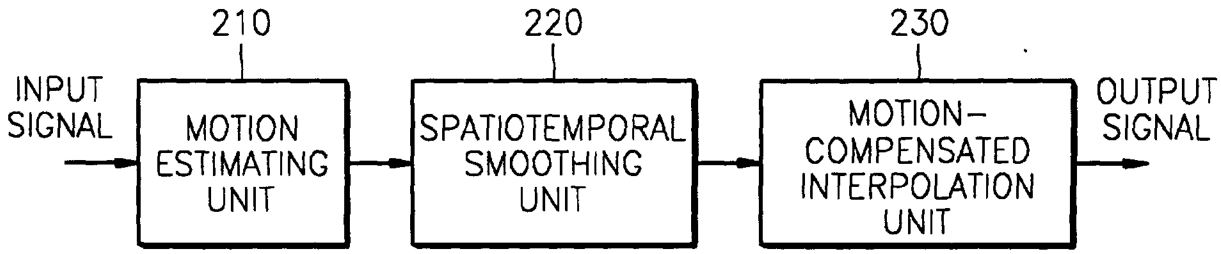

210
220
230
INPUT SIGNAL
MOTION ESTIMATING UNIT
SPATIOTEMPORAL SMOOTHING UNIT
MOTION-COMPENSATED INTERPOLATION UNIT
OUTPUT SIGNAL

FIG. 10A

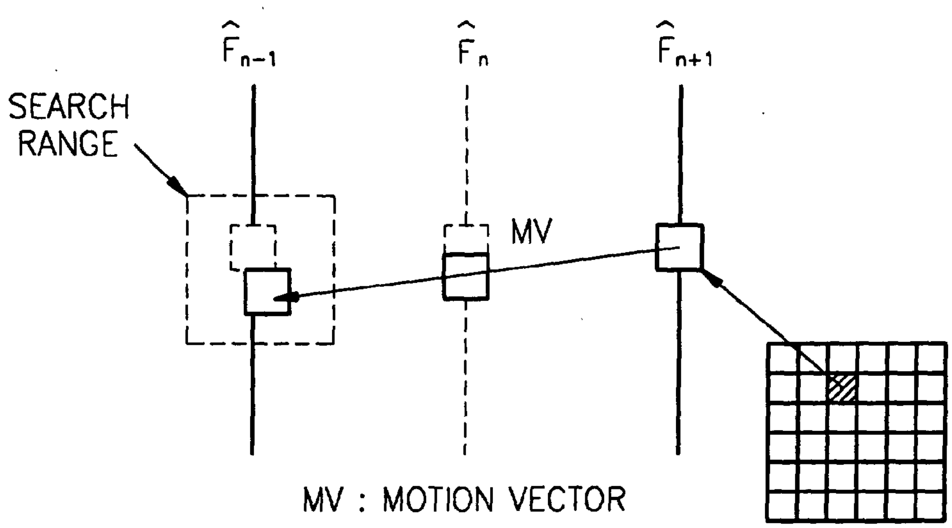

$\hat{F}_{n-1}$
$\hat{F}_{n}$
$\hat{F}_{n+1}$
SEARCH RANGE
MV
MV : MOTION VECTOR

FIG. 10B

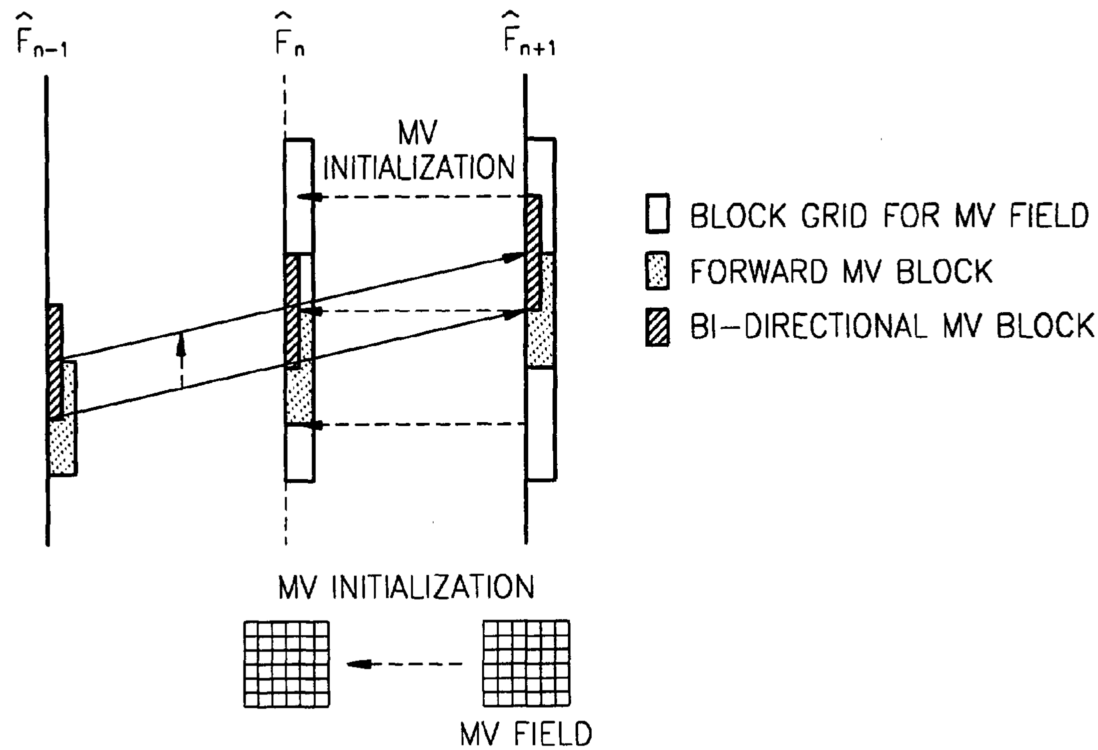


FIG. 10C

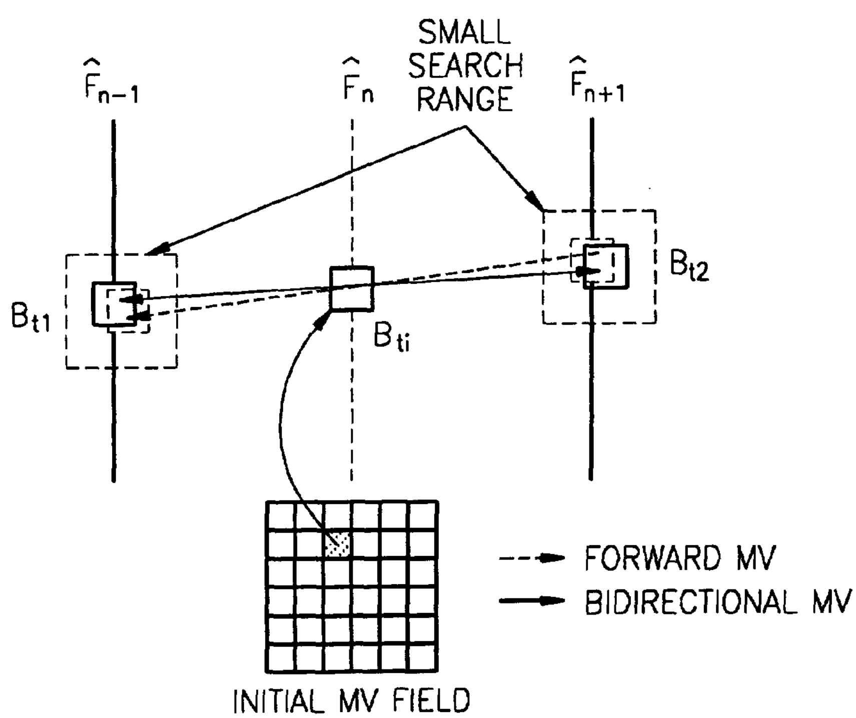


FIG. 11

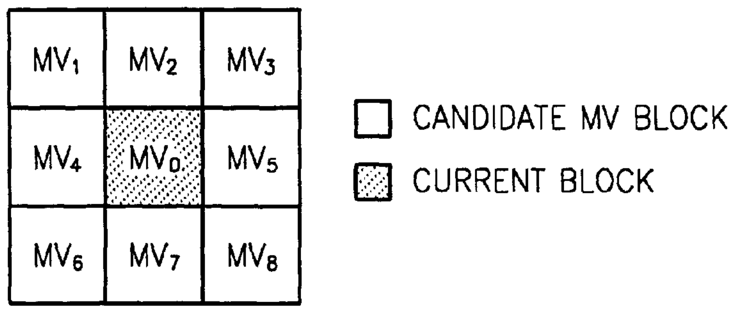

MV1
MV2
MV3
MV4
MV0
MV5
MV6
MV7
MV8
CANDIDATE MV BLOCK
CURRENT BLOCK

FIG. 12

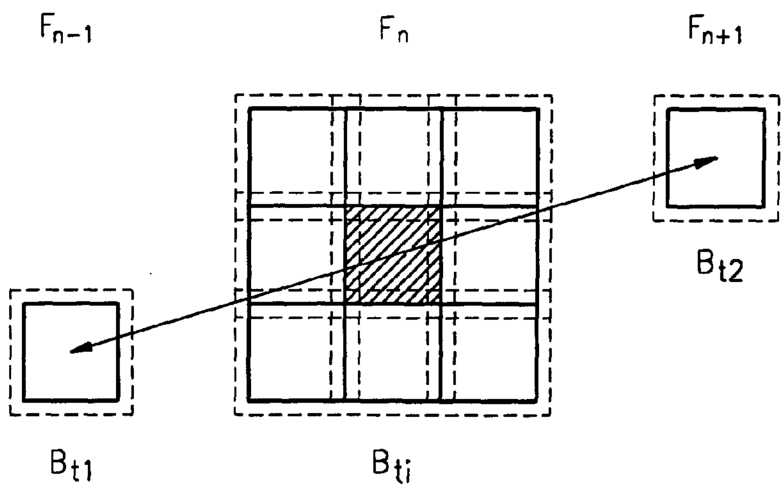

Fn-1
Fn
Fn+1
Bt2
Bt1
Bti

FIG. 13

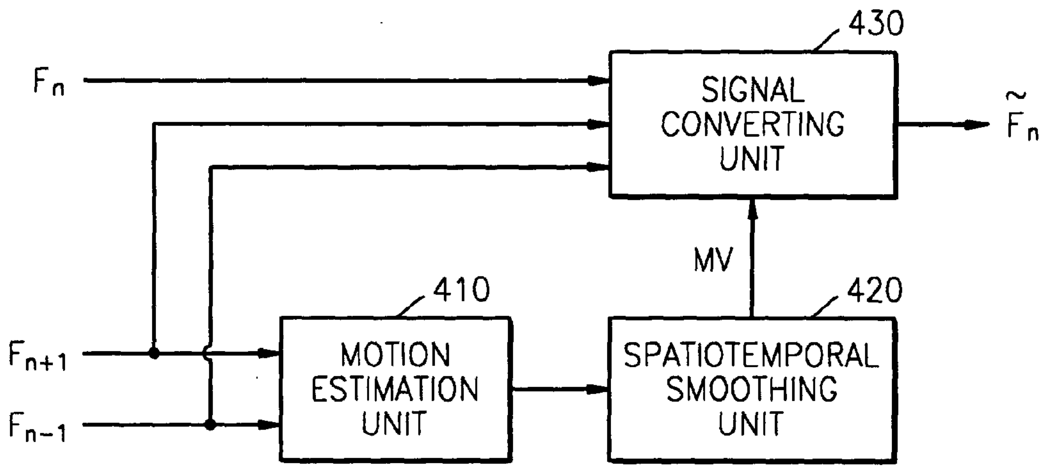

430
SIGNAL CONVERTING UNIT
F_n
$\tilde{F}_n$
MV
410
420
F_{n+1}
F_{n-1}
MOTION ESTIMATION UNIT
SPATIOTEMPORAL SMOOTHING UNIT

FIG. 14

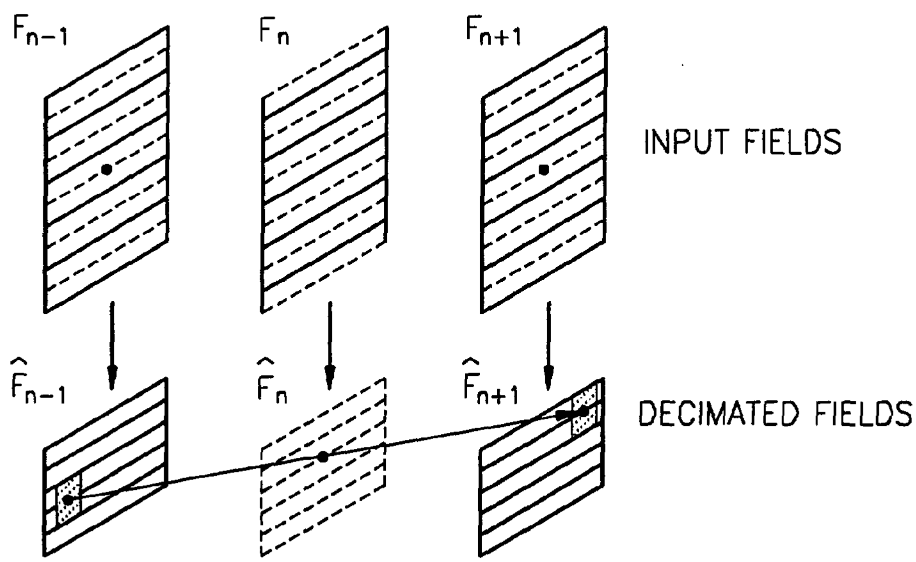

F_{n-1}
F_n
F_{n+1}
INPUT FIELDS
$\hat{F}_{n-1}$
$\hat{F}_n$
$\hat{F}_{n+1}$
DECIMATED FIELDS

FIG. 15

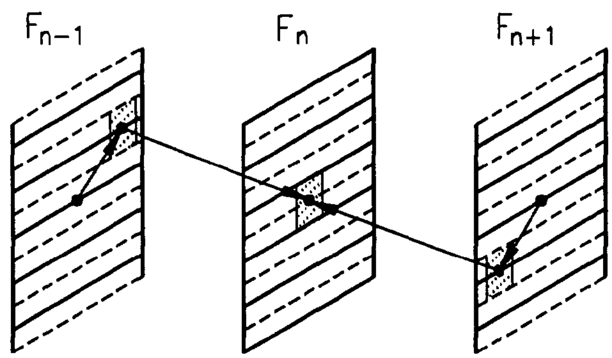


FIG. 16

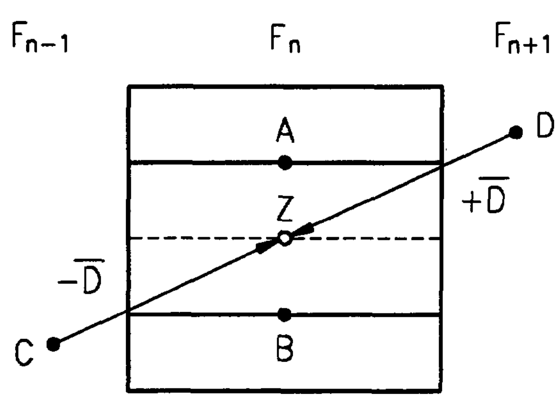
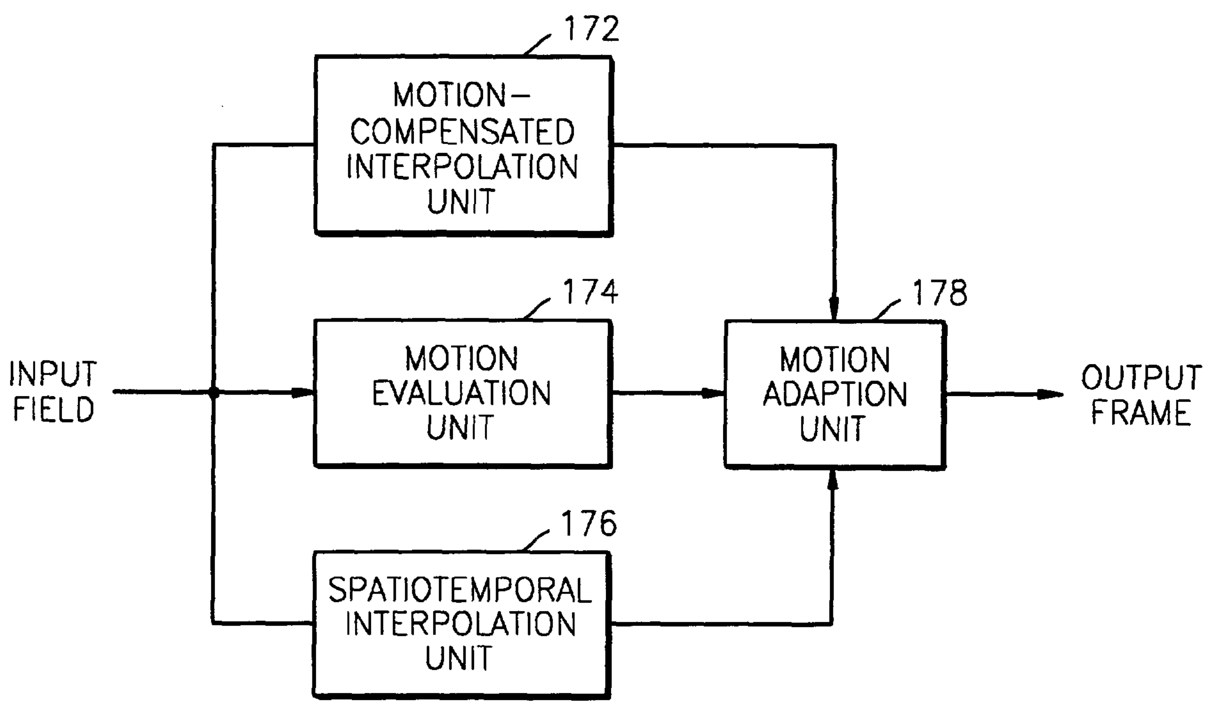


FIG. 17


172
MOTION-
COMPENSATED
INTERPOLATION
UNIT
174
MOTION
EVALUATION
UNIT
178
MOTION
ADAPTION
UNIT
176
SPATIOTEMPORAL
INTERPOLATION
UNIT
INPUT
FIELD
OUTPUT
FRAME

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 164 792 A3

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(51) Int Cl.^{7}: **H04N 7/01**

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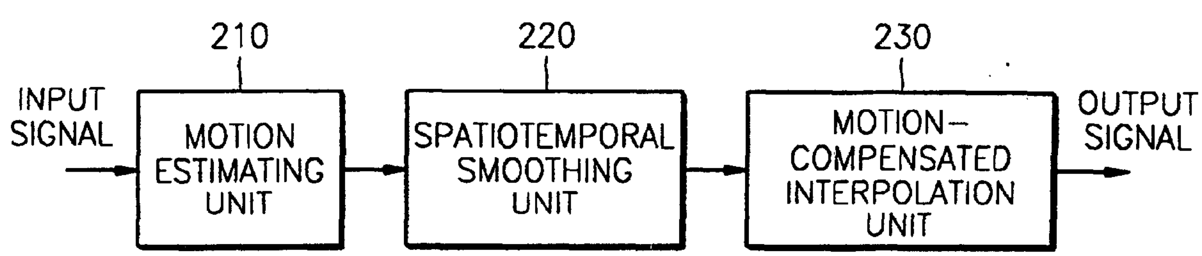
(54) **Format converter using bidirectional motion vector and method thereof**

(57) A format converter which performs frame rate conversion and de-interlacing using a bidirectional motion vector and a method thereof are provided. The method includes the steps of (a) estimating a bidirectional motion vector between the current frame and the previous frame from a frame to be interpolated; setting the motion vector of a neighboring block that has the minimum error distortion, among motions vectors estimated in the step (a), as the motion vector of the current block; and (c) forming a frame to be interpolated with the motion vector set in the step (b).

FIG. 9



EP 1 164 792 A3

European Patent Office

PARTIAL EUROPEAN SEARCH REPORT

which under Rule 45 of the European Patent Convention shall be considered, for the purposes of subsequent proceedings, as the European search report

Application Number EP 01 10 4859

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	US 5 526 053 A (DORRICOTT ET AL.) 11 June 1996 (1996-06-11) * abstract * * column 5, line 63 - column 9, line 39 * ---	1-3,5,6, 8,9	H04N7/01
A	US 4 691 230 A (KANEKO ET AL.) 1 September 1987 (1987-09-01) * abstract * ---	1,5,6,9	
A	WO 99 67952 A (HITACHI) 29 December 1999 (1999-12-29) * abstract * & EP 1 104 970 A (HITACHI) 6 June 2001 (2001-06-06) * abstract * * page 5, line 43 - page 6, line 46 * * page 7, line 54 - page 10, line 34 * ---	1	
X	WO 94 16522 A (THOMSON-CSF) 21 July 1994 (1994-07-21) * page 2, line 24 - line 35 * * page 6, line 12 - page 9, line 12 * --- -/--	10,15	TECHNICAL FIELDS SEARCHED (Int.Cl.7) H04N

INCOMPLETE SEARCH

The Search Division considers that the present application, or one or more of its claims, does/do not comply with the EPC to such an extent that a meaningful search into the state of the art cannot be carried out, or can only be carried out partially, for these claims.

Claims searched completely :

Claims searched incompletely :

Claims not searched :

Reason for the limitation of the search:

see sheet C

Place of search	Date of completion of the search	Examiner
THE HAGUE	19 June 2003	Berwitz, P

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

European Patent Office

INCOMPLETE SEARCH SHEET C

Application Number
EP 01 10 4859

Claim(s) searched completely:
1-17

Claim(s) not searched:
18-20

Reason for the limitation of the search:

The wording of claims 18 to 20 is such that a lack of clarity within the meaning of Article 84 EPC arises to such an extent as to render a meaningful search of the claims impossible.

Consequently, the search has been carried out for those claims which, although not clear, appear to be searchable in the light of the description, namely claims 1 to 17.

European Patent Office

PARTIAL EUROPEAN SEARCH REPORT

Application Number
EP 01 10 4859

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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P,A	WO 00 38423 A (INTEL) 29 June 2000 (2000-06-29) * page 7, line 15 - page 9, line 23 *	1,2,4,5	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)

EPO FORM 1503 03.82 (P04C10)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 01 10 4859

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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19-06-2003

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			JP	8505496	T	11-06-1996
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			JP	8163573	A	21-06-1996
			JP	8186802	A	16-07-1996
			JP	9037214	A	07-02-1997
			US	5886745	A	23-03-1999
WO 0038423	A	29-06-2000	AU	2382600	A	12-07-2000
			CA	2355945	A1	29-06-2000
			EP	1142327	A1	10-10-2001
			JP	2002534014	T	08-10-2002
			WO	0038423	A1	29-06-2000

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82